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NATURE AND CONTROL OF APPLE-SCALD

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NATURE OF APPLE-SCALD

EFFECT OF REMOVAL FROM STORAGE

It is a quite generally accepted idea that apple-scald is due to the warming up of the fruit after it has been removed from cold storage. This idea comes from an erroneous interpretation of very familiar facts (*2*).[1] It is true that apples do not show scald while held continuously in storage at 0°C. (32° F.) and that they seldom show it under commercial cold-storage conditions where the air must from necessity sometimes vary slightly from any desired temperature. It is also true that apples that have been stored for several months in tight packages or closed rooms may show very bad scald after a few days' exposure to warm air. Under such circumstances, it is natural to conclude that the warming up of the fruit is the cause of the scald; but the facts of the case are that the apples are already potentially scalded, and the higher temperatures merely allow the death processes of the apple tissue to be carried out. The real cause of the disease is to be found in the conditions of transportation and storage to which the fruit is subjected during the first few weeks after it is removed from the tree. Healthy apples do not develop scald upon removal from cold storage, even when transferred at once to living-room temperatures.

RELATION OF THE COMPOSITION OF THE STORAGE AIR TO APPLE-SCALD

The fact that outside air produces such serious results on potentially scalded apples has led to a belief that apples should be kept away from fresh air and air currents as much as possible at all times; but carefully controlled storage experiments have shown conclusively that when the fruit is stored in open packages, scald can be entirely prevented by thorough stirring of the storage air. The question naturally arises as to the nature of the harmful substances that are carried away from the fruit by this air movement.

HUMIDITY.—Many storage men hold the opinion that excessive moisture may bring about apple-scald. The writers have made a number of carefully controlled experiments with apples held under different humidities and, as reported later, have also followed up the moisture conditions

[1] Reference is made by number (italic) to "Literature cited," p. 240.

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in commercial cold storage. The results indicate that when moisture remains condensed in drops on the fruit there may be a slight increase in the development of scald, but apparently because of the more restricted aeration of the apple tissue rather than from any harmful effect of the water itself. Apples stored in air that was saturated with moisture but constantly stirred have not developed scald, while similar apples in dry, stagnant air have become badly scalded. Apples have been exposed to outside air by throwing a cold-storage room open freely when the temperature would allow, and by rolling the barrels out of the storage room for one or two days each week; but scald has been reduced rather than increased by the treatment. (See p. 223.) Apples that have been picked wet or have had water poured over them after they were in the barrel have developed no more scald than others picked and packed when they were dry. The writers have found no evidence that excessive humidity plays any important part in the development of scald either under experimental or commercial storage conditions.

Oxygen.—The apple is a breathing organism, and under conditions of restricted aeration the percentage of oxygen in the air surrounding the fruit is reduced below normal. The question naturally arises as to whether this change in air composition has any influence upon the development of scald. To test this point, apples were stored in air which had the percentage of oxygen reduced from 21 to 6.9, and others in air which had the percentage of oxygen increased to 31.5. The amount of scald developed in each lot was compared with the amount on apples held in air having the normal percentage of oxygen. The reduced oxygen supply resulted in no increase in the amount of scald, and the increased oxygen supply gave no significant decrease in scald. In other experiments, Grimes apples were held in 100 per cent oxygen at 20° C. for four days and then removed from the oxygen and placed in moist chambers in normal air, part of the apples being then stored at 15° and part at 2.5°. Other apples were exposed to the same temperatures but were not given the preliminary oxygen treatment. Notes were taken at various times on the amount of scald, but no difference of any kind developed between the apples that had been first stored in oxygen and those that had not. The results are strikingly different from those reported later from similar experiments with carbon dioxid. (See p. 213.) The results of the various experiments seemed to prove conclusively that the small variations in the oxygen content that ordinarily occur in the storage air are not matters of importance in determining the development of scald.

Ozone.—Although an increased oxygen supply resulted in little or no decrease in the amount of scald, it seemed possible that a more powerful oxidizing agent might give different results. So in the fall of 1918 both laboratory and commercial cold-storage experiments were made with ozone.

In the laboratory tests a small but powerful ozone machine was used. In the preliminary experiments the ozonated air was used in its full strength as it came from the machine; but it injured the apples, soon producing brown dead spots at the lenticels. In the final experiments the air from the ozone machine was reduced to half strength by mixing with an equal volume of normal air. The apples used in the tests were Grimes from Vienna, Va. They were picked August 21 and the experiments started the following day. The fruit was stored in 8-liter jars that were fitted with 2-hole stoppers. Once every week ozonated air was drawn through these jars, the incoming current being freed at the bottom of the jars and the outgoing current taken from the top. The process was continued for 5 minutes and the jar then tightly corked and allowed to stand closed for the next 24 hours, after which the ⅝-inch stopper was removed and the jar left as a moist chamber for the remainder of the week. At the end of the ozone treatment the air from the exit tubes had a strong smell of ozone, but after 24 hours no ozone odor could be detected in the air of the jars. Part of the apples were stored at 15° and part at 0° C. In each experiment, control jars of apples were maintained that were identical with the others in every respect, except that in the weekly treatment normal air was drawn through instead of the ozonated air. Notes were taken at various times on the amount of scald and on the quality of the fruit, but no contrast of any kind was found between the apples that were treated with ozone and those that were not.

In the commercial cold-storage experiments, the ozone was obtained from a large 12-cylinder machine of the type most commonly used in egg storage rooms. The machine was operated from six to eight hours a day and from five to seven days a week. Six barrels of Grimes apples and six barrels of York Imperial were stored within a few feet of the machine, while similar lots were held as controls in another storage room. In each test, half of the apples were in ventilated barrels and half in barrels of the usual commercial type. The final notes on the Grimes apples were taken December 20 and the final notes on the York Imperial on January 18. Both varieties had scalded badly; but there was no contrast, in either the ventilated or unventilated barrels, between the fruit that had been exposed to ozonated air and that which had not. The results give little promise of scald prevention by increased oxidation.

Carbon dioxid.—Carbon dioxid is the gas produced in greatest quantity by storage fruit and is therefore the one that might most naturally be expected to produce harmful results. Experiments reported in an earlier paper (*2*), however, have shown that apples stored continuously in atmospheres having percentages of carbon dioxid similar to those in commercial storage, or even considerably exceeding them,

have shown no sign of injury and have developed less scald than similar apples held in air that was free from carbon dioxid. It was also found that apples could be made less susceptible to scald by storing them for a few days in an atmosphere composed entirely of carbon dioxid but that this treatment sometimes gave the apples a disagreeable alcoholic taste. In order to get further data as to the carbon-dioxid endurance of the apple, these latter experiments were repeated in the fall of 1918 with the period of storage in carbon dioxid shortened. The results are given in Table I. Lots A, B, and C were Grimes from Vienna, Va. They were picked August 20 and the experiment started the following day. The apples in lot D were Grimes from Wenatchee, Wash. They were shipped to Washington, D. C., in a pony refrigerator and the experiment started September 20. Lot E was Yellow Newtown apples from Winchester, Va. They were in cold storage until December 19, the date of starting the experiment. In all the tests the apples receiving prestorage treatment with carbon dioxid were removed from this gas at the end of the given number of days and stored in moist chambers in normal air. Thereafter they had the same air and moisture conditions as the controls had from the beginning of the experiment.

TABLE I.—*Effect of prestorage treatment with carbon dioxid upon the development of apple-scald*

Lot.	Prestorage conditions.		Storage temperature.	Number of weeks in storage.	Percentage of scald.	
	Temperature.	Number of days held.			Apples held in 100 per cent carbon dioxid during prestorage period.	Apples held in normal air during prestorage period.
	°C.		°C.			
A	30	2	10	10	10	52
B	20	4	15	10	35	60
C	20	4	2½	16	4	38
D	15	2	5	13	10	50
D_1	15	6	5	13	6	....
D_2	30	2	5	13	0	....
E	15	6	0	15	0	15

At the end of the various experiments the apples that had been treated with carbon dioxid were slightly greener than the untreated fruit but were apparently normal in taste and general appearance. A study of the last two columns of the table will show that the apples exposed to carbon dioxid developed much less scald than those that were not, giving further evidence that carbon dioxid has no tendency to produce the disease. The writers are of the opinion that the apparently beneficial effects of the carbon dioxid treatment are due to a general checking of the skin activities of the apple rather than to any specific

favorable effect upon apple scald. The results of these and earlier experiments show, however, that it is possible to use carbon dioxid as an agency for reducing apple scald and that this can be accomplished without evident injury to the apple.

While it seems to have been conclusively proved that carbon dioxid is not responsible for the occurrence of apple scald, it does not follow that high percentages of the gas in storage air are to be looked upon with favor, for such a condition would indicate a lack of air movement and an accumulation of other gaseous products of the apple as well as of carbon dioxid.

ARTIFICIAL SCALD.—Various attempts have been made to produce apple-scald artificially or to shorten its period of development by changing the composition of the air; but, as mentioned in the discussions of humidity and carbon dioxid, these have usually met with failure. Other experiments of this sort were made with alcohols, acids, and esters. In the preliminary tests the various substances were used in full strength and were placed in close proximity to the fruit, but this led to such serious and rapid injury from the more active agents that nothing resembling scald was produced. In the later experiments dilutions were made as indicated below, and the liquids were placed in the bottom of 8-liter jars with the apples supported in the top at a distance of approximately 12 inches from the chemicals. Twenty-five cc. of the material were used in each jar. All the jars were loosely stoppered. The experiments were made at 10° C. The results reported below are based on the appearance of the apples after they had been removed from the storage condition and had stood in a warm laboratory for 24 hours.

TABLE II.—*Effects of various volatile substances on Yellow Newtown and Rome Beauty apples*

Substances used.	Effects.
Water, control	Apples stored over water developed no scald or other injury.
Ethyl alcohol	At the end of 3 weeks no scald had developed, and the apples were apparently still normal.
Acetic acid	Rome Beauty apples showed injury at the end of 24 hours, but the effects did not resemble scald.
Alcohol 60 per cent, acetic acid 40 per cent.	Rome Beauty apples had their flesh killed and browned to a depth of ⅛ inch at the end of 48 hours, but the effects did not resemble scald.
Alcohol, 90 per cent, acetic acid, 10 per cent.	At the end of 7 days dead brown areas of various patterns were scattered over the skin of the apple. Many of the smaller spots were located at the lenticels. There was a clear-cut margin between the diseased and the healthy areas, and the flesh was affected to a much greater depth than it would be by scald. The brown spots were as common on the highly colored portions of the skin as on the poorly colored ones. There was but slight resemblance to typical scald.
Formic acid 100 per cent	No scald or other injury after 3 weeks.

TABLE II.—*Effect of various volatile substances on Yellow Newtown and Rome Beauty apples*—Continued

Substances used.	Effects.
Alcohol 80 per cent, ethyl acetate 20 per cent.	After 3 days' exposure to the vapors, Rome Beauty apples had a brown, cooked appearance, the red portions of the apples, however, being much less affected than the green portions.
Alcohol 90 per cent, ethyl acetate 10 per cent.	After 7 days, Rome Beauty and Yellow Newtown apples had the appearance of being typically scalded. The scalded areas occurred only on the green side of the fruit and shaded off in severity as the blush areas were approached. After standing in a warm room for 4 days the browning had spread into the flesh of the apple rather more rapidly than is usual with scald, but aside from this the diseased condition was typical of apple-scald.
Alcohol 80 per cent, amyl acetate 20 per cent.	Only Rome Beauty apples were tested. The results were practically the same as with 10 per cent ethyl acetate, a quite typical scald being produced.
Alcohol 90 per cent, amyl acetate 10 per cent.	Experiments were made with both Rome Beauty and Yellow Newtown apples. The former were removed at the end of 3 days and the latter at the end of 7 days. The results were similar to those reported for 10 per cent ethyl acetate, but the apples were even more typically scalded. The browned areas coincided in the most exact manner with the skin areas naturally susceptible to scald.
Ethyl malate 10 per cent......	Only about 10 cc. of the liquid were used, and the apples were placed in a smaller jar than those mentioned above. No scald or other injury had been produced at the end of 3 weeks.
Ethyl butyrate................	Experiments somewhat similar to those described above gave results very much like those obtained with ethyl acetate and amyl acetate.

The results reported in Table II show that it is possible to produce an apparently typical apple-scald within a few days by exposing the fruit to the vapors of certain dilute esters. The fact that the disease can be thus produced artificially when connected with the additional fact that the apples themselves are known to give off esters or related gases makes it seem probable that these substances play an important part in the development of scald as it occurs in commercial storage.

GAS ABSORBENTS AS SCALD PREVENTIVES

In an earlier paper (5) experiments were reported showing that scald can be practically prevented by wrapping the apples in paper that has been infiltrated with fat or oil. Other experiments are reported later in the present paper (see p. 233) that give full confirmation of these results and also make it clear that the beneficial effects of the wrappers are not due to modifications in the moisture or the carbon-dioxid content of the air surrounding the apple. It is well known that fats and oils have a great absorbing power for esters and other odorous gases, and because of this property they are used commercially in the extraction of perfumery. Cow butter takes up odors so readily that it is usually rendered unpal-

atable if held in storage with other food products. In view of these facts there seems to be little doubt that the beneficial effects of the fats and oils in the wrappers are due to the absorption of esters or similar products thrown off by the apple. The hypothesis is given further support by the fact that the fats and oils which are known to have a great absorbing power for gases give more complete control of scald than paraffin and similar waxes that are generally recognized as being more inactive toward these gases, and also by the results in the experiments reported above in which scald was produced artificially by exposing apples to various esters.

It is generally recognized in the apple trade that greasy, waxy apples do not scald as soon or as badly as the others. The above hypothesis offers a possible explanation for this fact, the wax of the apple, like that in the wrapper, apparently serving as an absorbent for the harmful gases.

TISSUES AFFECTED BY APPLE-SCALD

Scald is typically a skin disease of the apple. In the early and more typical stages of the trouble, only the five or six surface layers of cells that form the color-bearing tissue of the apple are affected. With long continued unfavorable conditions the apple tissue may become dead, brown, and rotlike to a depth of ⅛ to ¼ inch, and occasionally the disease spreads practically to the core. Reference is made here to the scald itself; but with the death of the protective skin layer, various rot organisms have free access to the softer tissues beneath and usually play an important part in hastening the destruction of the apple. Not all portions of the skin are equally susceptible to scald. The highly colored areas of red apples are affected only in the most extreme cases of scald. Often when the poorly colored areas are badly and deeply scalded, the diseased condition will shade off into a mere brown tint of the skin as the margin of the blush area is approached. The chemical changes that occur in the reddening of the fruit apparently produce a skin condition that is highly resistant to scald.

The statement is quite generally current that apples that still show the leaf green are very much more susceptible to scald than those which have become slightly yellowed. As a rough statement of the facts, this may be approximately true. The observations of the writers, however, indicate that while green apples, in general, are more susceptible to scald than ripe ones, those still having the leaf green are very much less susceptible than those that have just begun to turn yellow, and often less susceptible than those in which the ground color has become a deep yellow. They have also observed that while green apples may finally become more severely scalded than riper ones, the latter usually scald first if they develop the disease at all. In spite of these qualifications, it is still true that scald can be greatly reduced and delayed by leaving the apples on the tree till well matured.

INFLUENCE OF ORCHARD CONDITIONS

It is generally admitted that the susceptibility of apples to scald probably varies with orchard conditions, but little experimental data has ever been published on the subject. In the fall of 1918 apples were secured from various soil and orchard conditions at Wenatchee, Wash., for comparative storage tests on this point. In one test, Grimes apples from lightly irrigated trees growing in heavy clay soil were compared with similar apples from lightly irrigated trees on alluvial sand receiving a spring application of 10 pounds of sodium nitrate per tree. The apples were stored in the usual box packages in commercial cold storage. They were removed to a temperature of 15° C. (59° F.) on February 6 and notes taken February 15. The apples from the heavy clay soil had 35 per cent of scald and those from the heavily fertilized sandy soil 60 per cent of scald.

Experiments were conducted also with apples from a Grimes orchard in which irrigation experiments were being made. The orchard was in alfalfa and the soil of the various plots was quite uniform. The contrasts in irrigation were started the first of July and maintained for the rest of the season. With the heavily irrigated plot the soil moisture was kept at approximately 50 per cent of saturation, and with the lightly irrigated one at approximately 20 per cent of saturation, while with the third plot the soil moisture was kept at approximately 20 per cent from July 1 to August 15, and then at approximately 50 per cent the remainder of the season. The methods of irrigation, soil sampling, etc., were the same as those reported in an earlier paper (*4*) and will not be repeated here. The apples were picked on September 18, when mature but not overripe, and placed in storage the following day. They were removed from storage February 5 and were held at a temperature of 15° C. (59° F.) for one week before notes were taken. In experiment A one box of apples from each plot was used under each storage condition. In experiment B separate records were made for the apples of different sizes. There were from 1 to 6 pecks of each size under each storage condition. The results are given in Table III.

The apples from the plot receiving light irrigation early and heavy irrigation late developed about twice as much scald as those from the plot receiving heavy irrigation continuously and three to four times as much as those from the lightly irrigated plot.

It is particularly interesting to note that the increased amount of scald on the heavily irrigated apples was not due to their larger size, since the increase was as great on the small apples as on the large ones. It has been observed in an earlier publication (*5*) that large apples often scald worse than small ones. The foregoing results indicate that in the present case size is a secondary factor, the real cause of the increased scald being

some forcing agency, such as heavy irrigation, that has apparently rendered both large and small apples more susceptible to the disease.

TABLE III.—*Effect of orchard irrigation upon the development of scald in storage: Experiments with Grimes apples at Wenatchee, Wash., 1918*

Kind of storage.	Irrigation.	Percentage of scald.				
		Experiment A.	Experiment B.			
			Apples 2¾ inches and smaller.	Apples 2¾ to 3 inches.	Apples 3 to 3¼ inches.	Apples 3¼ to 3½ inches.
Cellar	Heavy	83	92	88	90	73
	Light	22	23	21	15	No apples.
	Light followed by heavy	50				
Air-cooled	Heavy	59	42	56	64	75
	Light	17	14	19	5	No apples.
	Light followed by heavy	40				
Cold	Heavy	69	53	79	75	61
	Light	23	6	27	28	No apples.
	Light followed by heavy	57				

RELATION OF TEMPERATURE TO THE OCCURRENCE OF APPLE-SCALD

The temperature relations of apple scald have been rather fully discussed in earlier reports (5). The rate of scald development increases with a rise in temperature; between 0° and 20° C. each rise of 5° hastens the time of scald appearance by two to six weeks, the greatest contrast occurring between 5° and 10° and the least between 15° and 20°. At 0° scald does not become evident. The apples become latently or potentially scalded but give little evidence of it until removed to a warmer temperature. At temperatures of 25° and above it has not been found possible to produce apple-scald, although other physiological troubles, such as internal breakdown, have developed all the more rapidly at these temperatures. Scald has been greatly delayed and in some cases apparently entirely prevented by bringing apples out after four or five weeks in commercial cold storage and giving them a thorough airing for 24 hours at a temperature of 22°. The hypothesis that scald is due to the accumulation of apple esters may furnish at least a partial explanation for the peculiar effects of the higher temperatures. The fruit esters are in general quite volatile, and their rate of vaporization is greatly increased by a rise in temperature. It seems possible that the slight increase in the rate of scald development in passing from 15° to 20° and the absence of the disease at 25° and 30° may be partly if not entirely due to the greater vaporization of the harmful products at these higher temperatures. It should not be overlooked,

however, that there is a marked change in the general ripening processes of the apple at the higher temperatures and that there may be much more fundamental reasons than the one suggested above for the absence of scald at these temperatures.

EXPERIMENTS IN THE CONTROL OF APPLE-SCALD

In the fall of 1918 apple storage experiments were started in Wenatchee, Wash., Winchester, Va., and Washington, D. C. In the smaller lots the apples were carefully selected from the tree, and in the larger lots they were taken as they came from the packing table. In obtaining records on the degree of scald the maximum scald that had been observed on the variety was taken as 100, and the amount of scald in a particular case was determined by its relation to this standard. Consideration was given to the area and depth of the scald as well as to the number of apples affected.

As previously mentioned (p. 211) apples may be potentially or latently scalded and yet not show it while held continuously at 0° C. (32° F.). In order to get the actual condition of the fruit as it came from storage, it was therefore held at a temperature of 20° C. (68° F.) for three days before the final notes were taken.

RELATION OF MATURITY OF FRUIT TO APPLE-SCALD

Powell and Fulton (*8*) were apparently the first to call attention to the importance of the maturity of the fruit in the control of apple-scald. Beach (*1*), Greene (*6*), Markell (*7*), Ramsey (*9*), and others have published confirmatory data. As pointed out earlier in this article (p. 217), the writers have found some definite exceptions to the rule that green fruit scalds worse than ripe, but in general their experimental data support the work of earlier investigators.

Table IV gives the results obtained with early and late pickings of Grimes, Rome Beauty, and York Imperial apples. The fruit was stored promptly in all tests. The Grimes and Rome Beauty apples were held in air-cooled cellar storage at Wenatchee, Wash. During September the average temperature of the cellar was 15° C. (59° F.), and the average humidity 75 per cent; during October the average temperature was 11° C. (51.8° F.), and the average humidity 72 per cent; and for the remainder of the storage period the average temperature was 2.5° C. (36.5° F.), and the average humidity 82 per cent. There was a daily fluctuation of from 2° to 4° C. The data given in the table were obtained after the apples had been held at 20° C. (68° F.) for nine days. The percentages in each case are practically double those recorded at the time of removal from cellar storage. One box of apples was used from each picking. The York Imperial apples were held at 0° C. (32° F.) in direct expansion commercial cold storage at Winchester, Va. Three barrels of apples were used under each condition in each test.

All the apples were practically free from scald when removed from storage. The data reported were obtained after the fruit had been held at 20° C. (68° F.) for three days.

TABLE IV.—*Relation of maturity of fruit to apple-scald*

Variety and location.	Package.	Date of picking.	Condition of fruit.	Date of note taking.	Weeks in storage.	Percentage of scald.
Grimes at Wenatchee, Wash.	Box	Sept. 7	Immature	Feb. 15	23	52
		Sept. 17	Mature commercial picking.	...do	22	30
		Oct. 2	Ripe	...do	19	18
Rome Beauty at Wenatchee, Wash.	.....do	..do	Green	Mar. 15	23	20
		..do	Well-colored	...do	23	6
		Oct. 21	Ripe to overripe	...do	21	0
Rork Imperial at Winchester, Va.	Commercial barrel.	Oct. 1	Rather immature	Jan. 28	17	28
		..do	.....do	Feb. 25	21	45
		Oct. 29	Mature	...do	17	25
Do	Ventilated barrel.	Oct. 1	Rather immature	Jan. 28	17	11
		..do	.....do	Feb. 25	21	18
		Oct. 29	Mature	...do	17	0

In all tests the early picked fruit developed more scald than the late picked. A study of the results on York Imperial might indicate that this was largely due to the fact that the early picked apples had been in storage longer. To get a fair test of the relative susceptibility of the two pickings to scald, the February 25 data on the October picking should be compared with the January 28 data on the October 1 picking, thus giving an equal storage period (17 weeks) for each lot. This method of comparison greatly reduces the contrast between the early picked and the late picked fruit, but the latter still maintains a superiority in scald resistance. The great difficulty of scald control by means of maturity lies in the fact that it is often impracticable to leave the fruit on the tree late enough to secure the desired results.

AERATION AS A PREVENTIVE FOR APPLE-SCALD

It has been proved by carefully controlled experiments that apple-scald can be completely prevented by giving the fruit sufficient aeration. This is readily accomplished with small lots of fruit in experimental storage, and the following experiments indicate that the principle can be used to advantage under commercial storage conditions.

AERATION IN DELAYED STORAGE.

There is no period in the storage life of the apple when aeration is so important as in the first week or two after the fruit is removed from the tree, especially in cases where it is impossible to hold it at low temperatures. Table V gives the results of several experiments in delayed storage. Three barrels or three boxes of fruit were used under each condition of each test. They were all held in commercial cold storage

but were removed to a temperature of 20° C. (68° F.) and held for three days before the final notes were taken. The apples used were as follows:

A, Grimes from Franklin, Va.; picked August 30; final notes taken December 20.

B, Rome Beauty from Franklin, Va.; picked September 27; final notes taken January 28.

C, York Imperial from Greenwood, Va.; picked October 10; final notes taken January 31.

D, Grimes from Winchester, Va.; picked September 10; final notes taken January 16.

E, Stayman Winesap from Winchester, Va.; picked September 25; final notes taken January 22.

F, York Imperial from Winchester, Va.; picked October 1; final notes taken February 11.

G, Rome Beauty from Wenatchee, Wash.; picked October 2; final notes taken March 25.

TABLE V.—*Effect of delayed storage and of aeration during delay*

Variety.	Treatment.	Percentage of scald.		
		Commercial barrel.	Ventilated barrel.	Box.
A, Grimes.	Immediate storage	35	30	.....
	Delayed 10 days in open packing shed	12	3	.....
	Delayed 10 days in sun in boxes	12	......	.....
B, Rome Beauty.	Immediate storage	28	20	.....
	Delayed 10 days in warm laboratory, temperature 21.1° to 23.9° C. (70° to 75° F.).	80	0	.....
C, York Imperial.	In transit, by express, 3 days	20	8	.....
	In transit, by freight, 15 days	60	17	.....
D, Grimes.	Immediate storage	58	12	.....
	Delayed 9 days in closed packing shed, temperature 15.5° to 23.9° C. (60° to 75° F.).	47	12	.....
E, Stayman Winesap.	Immediate storage	50	16	.....
	Delayed 6 days in hall of cold-storage plant, temperature 10° to 12.8° C. (50° to 55° F.).	70	12	.....
	As above but delayed 10 days	70	15	.....
F, York Imperial.	Immediate storage	35	25	.....
	Delayed 8 days in hall of cold-storage plant, temperature 12.8° to 15.5° C. (55° to 60° F.).	50	30	.....
	As above but delayed 15 days	65	35	.....
G, Rome Beauty.	Immediate storage	......	......	12
	Delayed 9 days in the open, in the shade, temperature 5.6° to 15° C. (42° to 59° F.).	......	......	0
	Delayed 9 days in a closed room, temperature 7.2° to 12.8° C. (45° to 55° F.).	......	......	7

If a study is made of the results in the first column, it will be seen that in four out of six tests scald was greatly increased by delayed storage, and in the other two (A and D) it was quite definitely decreased. The tests in which there was a decrease are those in which the apples received the greatest amount of aeration during the delay. With the

ventilated barrels, scald was greatly decreased by delay in two of the tests, decidedly increased in one, and apparently but little affected in the others. With the boxes, scald was slightly decreased by delay in a closed room and entirely prevented by delay in the open. The most striking feature of the table, however, is seen when the scald in the delayed, ventilated barrels is compared with that in the immediate storage, commercial barrels. The good effects of the more open package have far more than offset any bad effects from the delay, and have resulted in reducing the scald to about one-fourth of that on the immediately stored fruit in the unventilated or commercial barrel. Delayed storage may evidently be either favorable or unfavorable to the development of scald, depending upon the conditions under which the fruit is held. If it is possible to give good aeration during the delay, the results may be distinctly beneficial to the fruit, especially if it is rather immature; but as is shown in Table V, delay in closed rooms or in unrefrigerated cars is likely to result in the development of serious scald later in storage.

TEMPERATURE CHANGES AS A MEANS OF AERATION

It is generally believed that changes in the temperature of the fruit or the storage room are likely to produce serious results. The experi ments reported in Tables VI, VII, and VIII indicate that so far as apple-scald is concerned, temperature changes may sometimes prove beneficial.

The apples used in Table VI were Grimes from Vienna, Va. They were stored September 3, and notes were taken December 20. Two barrels of apples were used under each condition. The laboratory to which part of the apples were removed stood at a temperature of 20° C. (68° F.), and the apples were held there for 24 hours at a time. The hall into which other apples were rolled had an open window but was protected from outside winds. The temperature was from 2½° to 5° C. (4½° to 9° F.) warmer than that of the storage room. The apples were left in the hall for about 24 hours at a time.

In the experiment reported in Table VII the apples were from Wenatchee, Wash. The Rome Beauty apples were stored October 2 and the Stayman Winesap October 12. The notes on both were taken March 25. The storage room stood at 0° C. (32° F.). The engine room to which part of the apples were moved had a temperature of 14.4° C. (58° F.) during the time of the first airing, and a temperature of 12.8° C. (55° F.) during the second airing. The average temperature of the outside air during the first airing was 7.8° C. (46° F.), and at the time of the second airing 8.8° C. (48° F.). One box of apples was used under each condition.

In the experiment reported in Table VIII the apples were from Winchester, Va. The Arkansas apples were stored October 28, and the notes taken February 3; the Stayman Winesap stored September 25, and the

notes taken January 23; the York Imperial stored October 1, and the notes taken February 11; the Yellow Newtown stored October 25, and the notes taken April 7. Three barrels of each variety were left continuously in storage and three rolled into the hall for a 24-hour period once each week during the first 2½ months of storage. The temperature of the storage room stood at 0° C. (32° F.) or slightly above; during October the hall had a temperature of 7° to 10° C. (44.6° to 50° F.), and in the later months a day temperature of about 5° C. (41° F.) and a night temperature of approximately 0° C. (32° F.) The hall doors were kept open, giving free circulation of outside air. Resistance thermometer bulbs were forced into apples in the center of the barrels and temperature readings taken when the apples were removed to the hall and again when they were returned to storage. The temperature of the fruit was never raised more than 1° C. (1.8° F.) by exposure to the hall temperature for 24 hours. In all the different tests the apples were held at 20° C. (68° F.) for three days before the notes were taken.

TABLE VI.—*Effect of temperature changes upon apple-scald: Experiment at Washington, D. C.*

Lot No.		Percentage of scald.	
		Grimes in commercial barrel.	Grimes in ventilated barrel.
1	In cold storage continuously 16 weeks	35	30
2	As in 1 but at 20° C. (68° F.) 1 day at the end of 6 weeks' storage	31	18
3	As in 1 but at 20° C. (68° F.) 1 day each at the end of 6 and 11 weeks' storage	25	5
4	As in 1 but at 20° C. (68° F.) 1 day at the end of 11 weeks' storage	38	35
5	As in 1 but in cold-storage hall 1 day each at the end of 5, 7, and 11 weeks	......	10
6	As in 1 but in cold-storage hall 1 day each at the end of 7 and 11 weeks	35	5
7	As in 1 but in cold-storage hall 1 day at the end of 7 weeks	28	12
8	As in 1 but in cold-storage hall 1 day at the end of 11 weeks	35	23

TABLE VII.—*Effect of temperature changes upon apple-scald: Experiment at Wenatchee, Wash.*

Lot No.		Percentage of scald in boxes.	
		Rome Beauty.	Stayman Winesap.
1	In cold storage continuously	11	12
2	In engine room for 6 hours on Nov. 7 and again for 6 hours on Dec. 2	14	8
3	As in 2 but removed to the open air for the same 6-hour periods	9	13

TABLE VIII.—*Effect of temperature changes upon apple-scald: Experiment at Winchester, Va.*

Lot No.	Treatment.	Percentage of scald in commercial barrels.			
		Arkansas.	Stayman Winesap.	York Imperial.	Yellow Newtown.
1	In cold storage continuously	50	67	45	10
2	Moved from cold storage to storage hall 1 day each week during the first 2½ months of storage	30	34	45	12

No harmful effects of any kind were found to result from the exposure of the apples to outside air. A study of the tables shows that scald was either not affected or else was reduced by the treatment, the results apparently depending upon the amount of aeration the apples received while out of storage. In the experiment reported in Table VI, where the commercial barrels were removed to rather poorly ventilated rooms 1 to 3 times, the treatment had practically no effect upon scald, but in the experiment reported in Table VIII, where similar barrels were removed to a well-ventilated hall 8 to 10 times, scald was considerably reduced. While the aeration reported in Table VI was apparently too slight to affect the apples in the commercial barrels, the same treatment resulted in a decided reduction of scald in the ventilated barrels, the difference apparently being due to the better aeration secured by the more open package. It is interesting to note in Table VI that while the aerations given at the end of the seventh week of storage decidedly decrease scald, those at the end of the eleventh week had but little effect upon the disease. This is in agreement with data reported in an earlier publication (*5*), indicating that with Grimes apples aerations must be made during the first 8 or 9 weeks of storage in order to have any beneficial effect upon scald.

The barrels removed from the storage rooms were exposed to more breezes than those that remained, but the aeration received by the apples which were moved was doubtless greatly increased by the air currents set up as a result of the difference between the temperature of the fruit and that of the outside air.

AIR-COOLED STORAGE

Experiments were made to determine the comparative development of apple-scald in air-cooled and cold-storage plants. The results are given in Tables IX and X. The apples used in the experiment recorded in Table IX were from Winchester, Va. Three barrels of each variety were used under each condition. The Arkansas apples were stored October 18, and the final notes taken February 3; the Yellow Newtown stored October 25,

and the final notes taken April 7; and the York Imperial stored October 29, and the final notes taken February 20. All the apples were in direct expansion cold storage from the time of storing till October 31 and were therefore well cooled before being placed in the air-cooled storage. The direct expansion storage house was located at Winchester, Va., and the air-cooled plant at Gerrardstown, W. Va. Hygrothermograph records were kept for both plants throughout the storage season. In the direct expansion rooms, the temperature was held at 0° C. (32° F.) or slightly above; and the relative humidity ranged from 65 to 90 per cent, standing between 75 and 80 per cent during most of the storage season. In the air-cooled plant, the temperature ranged from 5° to 15° C. (41° to 59° F.) during the period from October 31 to November 20 and throughout the remainder of the storage period was fairly constant at 5° C. (41° F.), seldom varying from this temperature more than 1° in either direction. The relative humidity in the air-cooled plant ranged from 40 to 90 per cent, the daily variations often covering a large part of this range. The average relative humidity was approximately 65 per cent.

TABLE IX.—*Apple-scald in air-cooled storage: Experiment at Winchester, Va.*

Lot No.	Treatment.	Percentage of scald.			
		Ventilated barrels.	Commercial barrels.		
		York Imperial.	York Imperial.	Arkansas.	Yellow Newtown.
1	Cold storage, in aisle	1	25	50	10
2	Air-cooled storage Oct. 31 to Dec. 17, and cold storage the rest of the storage period	....	45	60	......
3	Air-cooled storage Oct. 31 to Nov. 26, and cold storage the rest of the storage period	3	25	55	35
4	Air-cooled storage Nov. 26 to Dec. 17, and cold storage the rest of the storage period	1	40	30	20

The experiments recorded in Table X were made in Wenatchee, Wash. The Grimes apples were picked September 18, and the Yellow Bellflower September 21. The notes on both were taken February 15. The Rome Beauty apples were picked October 2, and the Stayman Winesap October 4. Both were removed from storage March 17 and notes taken March 25. One box of each variety was used under each storage condition. The average temperature of the cold-storage plant was 5° C. (41° F.) during September and October, 1.8° C. (35.2° F.) during November, and 0° C. (32° F.) during the remainder of the storage period. The relative humidity ranged between 80 and 90 per cent, averaging approximately 85 per cent for the entire storage period. In the air-cooled plant the average temperature during September and October was 12.2° C. (54° F.),

during November 3.3° C. (38° F.), during December 2.2° C. (36° F.), and for the remainder of the storage period 0.8° C. (33.4° F.). In the air-cooled cellar the temperatures were those given in paragraph 4, page 220. All the apples were moved to a temperature of 20° C. (68° F.) one week before the final notes were taken.

TABLE X.—*Apple-scald in air-cooled storage: Experiments at Wenatchee, Wash.*

Lot No.	Treatment.	Percentage of scald in boxes.					
		Grimes.	Rome Beauty.	Stayman Winesap.	Yellow Bellflower.	Grimes. Heavily irrigated.	Grimes. Lightly irrigated.
1	Cold storage	35	11	12	15	69	23
2	Air-cooled storage	30	6	......	0	59	17
3	Cold storage 1 month, then air-cooled storage	42	......	4	......	......	......
4	Air-cooled storage 1 month, then cold storage	7	......	0	......	......	......
5	Cold storage 2 months, then air-cooled storage	40	10	[a]14	......	......	......
6	Air-cooled storage 2 months, then cold storage	60	7	[b]0	......	......	
7	Air-cooled cellar storage	......	......	......	......	83	22

[a] Cold storage 4 months. [b] Air-cooled storage 4 months.

In the West Virginia experiment, the apples in air-cooled storage scalded worse than those in cold storage, while in the experiment at Wenatchee, Wash., the apples in cellar storage were scalded most, the ones in cold storage next, and those in air-cooled storage least. The results appear to be contradictory, but are really in harmony with the fundamental facts. It was pointed out earlier in the paper that scald development is decreased by low temperatures and also by aeration. The temperatures in the cellar storage at Wenatchee and in the air-cooled plant at Gerrardstown, W. Va., were higher than those in the air-cooled plant at Wenatchee; and the air circulation in the first two places was also poorer than that in the last. So while the results reported in the table appear contradictory so far as air-cooled storage is concerned, they are in harmony with the laws of scald occurrence. Air-cooled storage conditions vary greatly with the weather and with the construction and management of the storage house, and the results on scald will necessarily vary accordingly. The infrequency of cool nights in the fall of 1918 made the management of air-cooled houses unusually difficult.

COLD-STORAGE SYSTEMS AND METHODS

Experiments were made at Wenatchee, Wash., and Winchester, Va., to determine the effect of ventilation and aeration in commercial cold-storage plants. The apples were held at 0° C. (32° F.) or slightly above

in all the different tests. In the Wenatchee experiment part of the apples were stored in a room cooled by direct expansion and the others in a room cooled by the bunker system. In the former experiment there was practically no air movement, while in the latter the apples were stored at a distance of about 3 feet from an opening in the outgoing air duct and were constantly fanned by an air current moving at the rate of 0.88 miles per hour. Two boxes of apples of each variety were used under each storage condition. The Grimes were stored September 18, the Stayman Winesap October 12, and the Rome Beauty October 2. All were in the direct expansion storage room till October 21, when half of each lot was moved to the bunker system storage. The final notes on the Grimes were taken February 15 and on the Stayman Winesap and Rome Beauty March 25. All the apples were held at a temperature of 20° C. (68° F.) for four days before the notes were taken.

TABLE XI.—*Apple-scald in direct expansion and bunker systems of cold storage*

Kind of storage.	Percentage of scald.		
	Grimes.	Stayman Winesap.	Rome Beauty.
Direct expansion	35	12	11
Bunker	1	0	8

The results would indicate that the bunker system was much more favorable to scald prevention than the direct expansion. It should be noted, however, that with the bunker storage the apples were given one of the most favorable locations in the room so far as air circulation was concerned. Anemometer readings showed that the air in the lower corners of the room was practically stagnant and but little affected by the air circulation above. What the results in Table XI do show is that a continuous air circulation at the rate of 0.88 mile per hour practically eliminates scald on box apples.

In the experiment at Winchester, Va., all the apples were stored in large rooms cooled by a direct expansion system, but the different lots were variously located so as to receive different amounts of aeration. One of the storage rooms had two outside windows, each 3 feet wide and 5 feet high, in the west wall of the room, and two similar windows in the east wall. The doors in the elevator shaft were near the east end of the room. The windows and doors were thrown open on cool nights and the outside air admitted freely into the storage room. A $\frac{1}{10}$ horsepower ventilating fan was sometimes used in one of the doors. Such breezes as were obtained were so soon dissipated that it was never possible to obtain anemometer readings at a greater distance than 10 feet from any of the windows.

Because of the infrequency of cool nights in the fall of 1918 and the difficulty of having somebody at the storage rooms at the right time, only five ventilations were given during the critical period for scald. The first of these was made on November 12, and the others followed at weekly intervals. Considerable benefit was apparently derived from these ventilations, but probably not as much as from the daily fanning of the doors in connection with the regular storage-house operations. The apples of lot 1, Table XII, were stored in a corner of the room in the bottom of the stack, those of lot 2 near a west window in the middle of a large stack, and those of lot 3 in an aisle between an east window and the door into the elevator shaft. The apples of lot 4 were in an aisle near the door of a second storage room that was similar to the first but had no windows and received no special ventilations. The Stayman Winesap apples were stored September 25, and the final notes taken January 23; the Arkansas stored October 28, and the final notes taken January 30; and the York Imperial stored October 1 and October 29, and the final notes taken February 14 and March 8. Three barrels of each variety were used under each storage condition.

TABLE XII.—*Aeration in commercial cold storage*

Lot No.	Storage location.	Percentage of scald.					
		York Imperial.				Stayman Winesap.	Arkansas.
		Stored Oct. 1.		Stored Oct. 29.			
		Ventilated barrels.	Commercial barrels.	Ventilated barrels.	Commercial barrels.	Commercial barrels.	Commerical barrels.
1	In corner in bottom of stack	......	80	......	......	......	......
2	Near window in middle of stack	15	44	......	......	49	......
3	In aisle near window	12	32	1	10	32	28
4	In aisle of unventilated room	15	35	5	28	67	50

Of the first three lots of apples, all from the same room, those in the bottom of the stack at a distance from the windows and doors were scalded practically twice as much as any of the others; those surrounded by other barrels but near a window were next, while those in an aisle near a window had least scald. The apples of lot 4 which were in the aisle of the unventilated room were, in general, much worse scalded than those of lot 3, which were in the aisle of the ventilated room.

The results of the two experiments show a very close relationship between air circulation in cold-storage plants and scald prevention. It seems evident that the general management of the rooms and the arrangement of the stacks and the aisles are important factors in securing aeration of the fruit. The renewal of the air in the storage room is of

minor importance compared with sufficient stirring of the air within the room to enable the apples to throw off their waste gases.

STORAGE PACKAGES

In a question where the aeration of the fruit is involved, the nature of the package naturally plays an important part. In an earlier paper (5) preliminary experiments were reported covering a number of different temperatures and a great many different varieties of apples and showing that scald could always be produced by storing the apples in moist chambers and could always be prevented by storing them in open containers. Preliminary experiments were also reported showing that scald could be reduced in commercial storage by the use of ventilated barrels. The results reported in the following paragraph give confirmatory evidence of the importance of open packages in commercial storage.

The data reported in Table XIII were obtained in Wenatchee, Wash. The Grimes apples were picked September 18, were held in a laboratory until October 4, and were then placed in cellar storage. The lard cans remained closed until the apples were removed from storage. The final notes were taken February 14. The Rome Beauty apples were picked October 3, were held in cellar storage till November 2, and were then placed in cold storage. The lard cans remained closed till the apples were removed from storage. The final notes were taken February 14. The Stayman Winesap apples were picked October 12, were held in a cool, well-ventilated place till October 19, and then the lard cans were opened and all of the apples transferred to cold storage. The final notes were taken March 25. All lots were held in the open in a warm laboratory for three or more days before the final notes were taken. The following results were obtained on unwrapped apples, but similar contrasts were also obtained on wrapped apples.

TABLE XIII.—*Closed packages in storage*

Variety.	Percentage of scald.	
	In lard cans.	In commercial boxes.
Grimes	42	24
Rome Beauty	68	25
Stayman Winesap	34	2

The results show that the tight package greatly increased the amount of scald.

The experiments reported in Table XIV were made in Winchester, Va., and Washington, D. C. The Grimes at Winchester were picked September 11, the Stayman Winesap September 25, the green York Imperial October 1, and the ripe York Imperial October 29. The Grimes at

Washington, D. C., were picked September 3, the Rome Beauty September 27, and the York Imperial October 10. The Grimes and Rome Beauty in the Washington experiment were from Franklin, Va., and the York Imperial from Greenwood, Va. The time of taking the final notes is given in the table. Three baskets and from 3 to 15 barrels of apples were used under each storage condition reported. The baskets held approximately a bushel of apples each and were of the low, tight form with overlapping slats. The ventilated barrels were made by cutting holes in the staves of the usual commercial barrels. Fifteen holes ¾ inch by 4 inches were made in each barrel, care being taken to have the openings well distributed and to avoid weakening the barrel by making cuts too near the bulge. A more satisfactory barrel can be obtained by having the cooper notch the staves before the barrel is made. The room in which the Winchester apples were stored received an occasional ventilation, while that in which the Washington apples were stored did not; but in both cases the apples were near the door.

TABLE XIV.—*Influence of baskets and ventilated barrels upon apple-scald*

Treatment.	Percentage of scald.						
	Ventilated room, Winchester, Va.				Unventilated room, Washington, D. C.		
	Grimes, Jan. 11.	Stayman Winesap, Jan. 23.	York Imperial.		Grimes, Dec. 20.	York Imperial, Jan. 23.	Rome Beauty, Jan. 28.
			Green, Feb. 14.	Mature, Feb. 20.			
Immediate storage:							
Commercial barrels	33	49	45	25	35	20	28
Ventilated barrels	8	16	15	1	30	8	20
Baskets	......	18	15	......	......	......	......
Delayed storage:							
Commercial barrels	29	76	65	......	12	60	80
Ventilated barrels	20	......	35	......	3	17	0
Baskets	......	25	45	......	......	......	......

The results with the baskets were similar to those with the ventilated barrels. With the immediate storage in the ventilated room, the ventilated barrels in every case reduced the scald to at least one-third of that in the commercial barrels; but with the fruit in the unventilated room, the ventilated barrels caused only a slight reduction in scald. In the delayed storage, the ventilated barrels resulted in a great decrease in scald in nearly every case, often reducing the percentage of the disease below that in the immediately stored commercial barrel. The results, as a whole, show that the ventilated barrel can be used to great economic advantage in the prevention of apple-scald.

The better aeration of the ventilated barrels was evidenced in the quicker rate of cooling on going into storage and in the composition of

the air of the barrels as well as in the prevention of apple-scald. These facts are brought out in a graphic manner in figures 1 and 2.

In the tests on rate of cooling, the temperature records were obtained by means of resistance thermometers, the thermometer bulbs being forced into apples in the middle of the barrels and the readings taken from the outside with an indicator without disturbing the fruit.

It will be noted from the curves in figure 1 that during the first few days in storage the apples in the ventilated barrels were from 5° to 10° F.

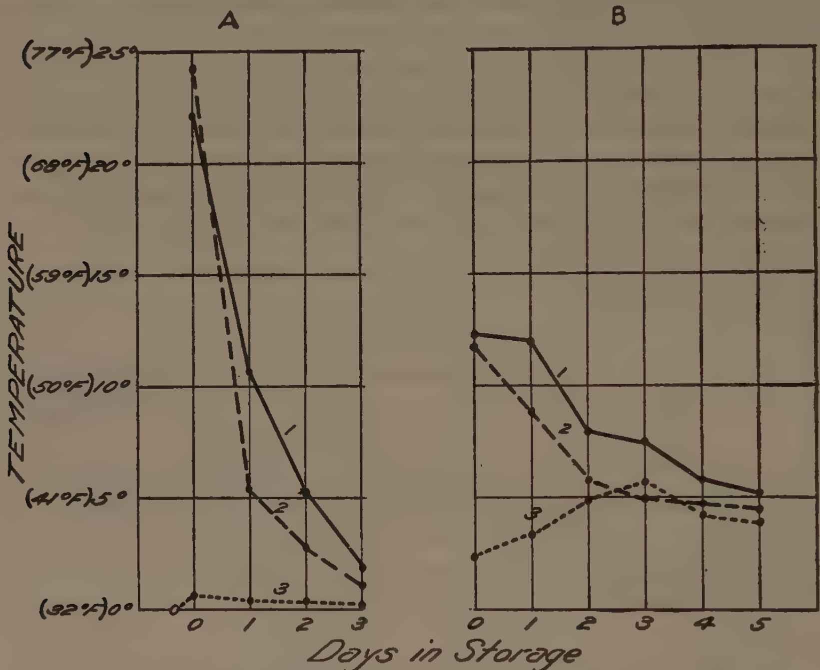

FIG. 1.—Relative rate of cooling of apples in commercial and ventilated barrels: A, Grimes apples in a storage room already filled with cold fruit; B, York Imperial apples in a storage room still receiving a large bulk of warm fruit. Curve 1 shows the temperature of the fruit in the center of a commercial barrel; curve 2, the temperature of the fruit in the center of a ventilated barrel; and curve 3, the temperature of the storage room.

colder than those in the commercial barrels. The quicker cooling secured by the ventilated barrels has a value in itself; but since the cooling is accomplished by air currents, the temperature contrast is also of interest as proof of the much freer exchange of air allowed by the more open barrels.

The relative carbon-dioxid content of the air in the ventilated and commercial barrels during the first weeks of storage is shown in figure 2. The gas analyses in figure 2, A, were made with the Pettersson gas apparatus and those in figure 2, B, with the Allen-Moyer Orsat apparatus. The samples were taken from the center of the barrel, small tubes having been arranged for this purpose at the time the apples were packed. A study

of the curves shows that there was usually more than twice as much carbon dioxid in the air of the commercial barrels as in the air of the ventilated barrels and but little more in the air of the ventilated barrels than in the air of the storage room. As was pointed out earlier in the paper (p. 213) small quantities of carbon dioxid do not appear to be harmful to apples; but since the fruit is continually giving off this gas, the quantity of it in the storage air does serve as an indicator of the extent of ventilation. The results give further evidence of a decided contrast between the aeration secured in the ventilated and commercial barrels.

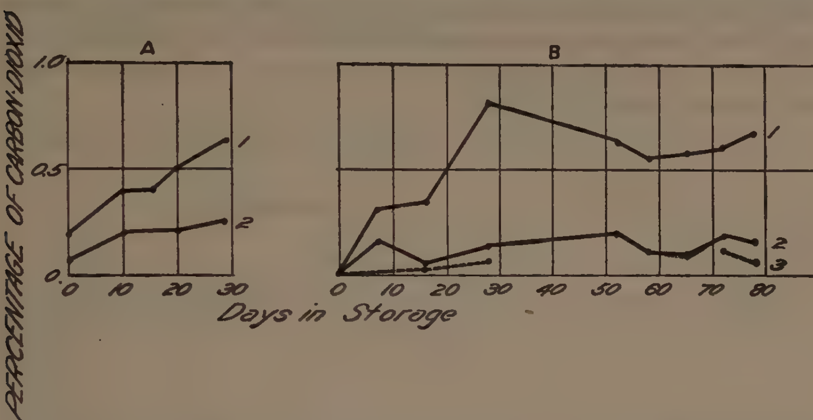

FIG. 2.—Relative carbon-dioxid content of the air in ventilated and commercial barrels during the first weeks of storage: A, Grimes apples in a storage room already filled with cooled fruit; B, York Imperial apples in a storage room still receiving a large bulk of fresh fruit. Curve 1 shows the percentage of carbon dioxid in the air of a commercial barrel; curve 2, the percentage in the air of a ventilated barrel; and curve 3, the percentage in the air of the storage room.

WAXES, FATS, OILS, AND OTHER GAS ABSORBENTS AS AGENCIES IN SCALD PREVENTION

Preliminary experiments were reported in an earlier paper (5) indicating that certain waxes and oils could be used as absorbents for the gases that are instrumental in producing apple-scald. In the following experiments the earlier results are confirmed and the list of gas absorbents greatly extended.

The neutral mineral oil wrappers were obtained from an oiled manila paper similar to that used in meat markets. The paraffin wrappers A were made by saturating ordinary apple wrappers with paraffin; the paraffin wrappers B and D were made from very light-weight commercial paraffin paper; and the paraffin wrappers C from a fairly heavy commercial paraffin paper. The glassine wrappers were from paper sold commercially under that name and apparently contained no wax or oil. All the other wrappers reported in Tables XV, XVI, and XVII were prepared by saturating the usual commercial apple wrappers with the given oil or wax.

The results reported in Table XV were obtained in experimental storage boxes, the separate lots of apples being held in moist chambers. Only 10 apples were used in each lot, but great care was taken that the different lots should be as nearly alike as possible. The tests were carried out under several different conditions with remarkably consistent results. The Grimes of August 21 were quite green and were placed under the given storage conditions the day after picking. The Grimes of October 29 were picked September 4, packed in barrels, and held in commercial cold storage from September 5 to October 28. The Rhode Island Greening apples were held in barrels in cold storage till November 5, and the Yellow Newtown apples till December 19. The wrapper experiments on the last three lots were started at the time the apples were removed from cold storage.

TABLE XV.—*Effect of oils, waxes, and other gas absorbents upon apple-scald*

Wrappers or packing.	Percentage of scald.								
	Grimes, Aug. 21, 1918.				Grimes, Oct. 29, 1918, after 14 weeks at—			Rhode Island-Greening, after 10 weeks at 15° C.	Yellow Newtown after 14 weeks at 5° C.
	After 10 weeks at—		After 16 weeks at—						
	15° C.	10° C.	2½° C.	0° C.	5° C.	2½° C.	0° C.		
None, control	60	40	43	58	90	52	53	85	40
Wrappers, commercial	45	......	38	50	63	55	70	41	35
Wrappers, paraffin A	12	......	......	20	60	25	35	......	6
Wrappers, paraffin B	12	......	15	30	......	......	......	......	......
Wrappers, paraffin C	15	......	32	38	......	......	......	......	......
Wrappers, glassine	......	......	......	......	......	......	......	70	50
Wrappers beeswax 30 per cent, vaselin 70 per cent	0	......	3	30	3	10	3	......	......
Wrappers, beeswax 30 per cent, olive oil 70 per cent	1	......	32	23	......	......	......	......	0
Wrappers, cacao butter 70 per cent, vaseline 30 per cent	1	......	20	18	......	......	......	......	......
Wrappers, cacao butter 70 per cent, olive oil 30 per cent	......	......	12	18	......	......	......	......	......
Wrappers, olive oil	......	......	......	......	......	......	......	......	......
Wrappers, neutral mineral oil	0	......	5	9	......	......	......	......	0
Wrappers, vaseline	0	......	18	18	......	......	......	......	0
Wrappers, cacao butter	3	......	20	35	......	......	......	0	0
Wrappers, beeswax	......	......	......	......	......	......	......	0	......
Wrappers, ceresin wax	......	......	......	......	......	......	......	9	0
Wrappers, Japanese wax	......	......	......	......	......	......	......	......	0
Wrappers, Carnauba wax	......	......	......	......	......	......	......	......	0
Wrappers, apple wax	......	......	......	......	......	......	......	......	10
Wrappers, ivory soap	......	......	......	......	......	......	......	......	0
Wrappers, glycerin	......	......	......	......	......	......	......	......	10
Wrappers, sugar, 100 per cent solution	......	......	......	......	......	......	......	......	30
Wrappers, lard	......	......	......	......	......	......	......	......	30
Wrappers, tallow	......	......	......	......	......	......	5	17	0
Wrappers, cow butter (unsalted)	......	......	......	......	......	......	7	0	0
Wrappers, linseed oil	......	......	......	......	......	......	4	0	0
Wrappers, neat's-foot oil	......	......	......	......	......	......	......	30	......
Wrappers, cottonseed oil	......	......	......	......	......	......	......	0	......
Wrappers, corn oil	......	......	......	......	......	......	......	40	......
Wrappers, peanut oil	......	......	......	......	......	......	......	20	......
Wrappers, castor oil	......	......	......	......	......	......	......	......	0
Charcoal, animal	15	35	......	......	......	......	......	......	0
Charcoal, wood	30	35	......	......	......	......	......	......	......
Charcoal, norite	60	30	......	......	......	......	......	......	......
Cork, granulated, wet	7	40	......	......	......	......	......	......	......
Cork, granulated, dry	1	......	......	......	......	......	......	......	......
Excelsior	30	......	......	......	......	......	......	......	......
Brick, granulated	30	......	......	......	......	......	......	......	......
Pumice stone, granulated	45	15	......	......	......	......	......	......	......
Oatmeal	5	20	......	......	......	......	......	......	......

Linseed oil and castor oil injured the skin of the apples wherever the wrapper was in close contact with the fruit.

The tests reported in Table XVI were made in a commercial cold-storage plant at Wenatchee, Wash. The apples were packed in boxes, one layer of apples being used for each treatment with a thick layer of newspapers between lots. The Grimes apples were stored September 18, were removed to a temperature of 20° C. (68° F.) on February 6, and the final notes taken February 15. The Stayman Winesap apples were stored October 12 and the Rome Beauty October 10. The Stayman Winesap apples were in storage two weeks before the fruit was wrapped. The apples of both these varieties were removed to a temperature of 20° C. (68° F.) on March 15 and the final notes taken March 24.

TABLE XVI.—*Box apples wrapped and unwrapped*

Kind of wrapper.	Percentage of scald.		
	Grimes.	Rome Beauty.	Stayman Winesap.
None, control	75	12	16
Commercial, no wax or oil	60	....	19
Paraffin B	....	....	11
Paraffin C	....	....	17
Paraffin D	....	6	....
Glassine	....	....	47
Paraffin 50 per cent, vaselin 50 per cent	0	1	....
Vaseline	2	0	....
Beeswax 30 per cent, vaseline 70 per cent	0	0	....
Cacao butter 70 per cent, vaseline 30 per cent	5	0	....
Beeswax 30 per cent, olive oil 70 per cent	0	3	....
Cacao butter 75 per cent, olive oil 25 per cent	0	1	....
Cacao butter	0	....	....
Mineral oil	....	....	0

The tests reported in Table XVII were made with eastern barreled apples. Only about one-third of the apples of the barrel were wrapped. The barrels were filled approximately half full of unwrapped apples, a bushel of wrapped apples added, and the remainder of the barrel filled with unwrapped apples. The Grimes were from Vienna, Va., and were placed in commercial cold storage at Washington, D. C., on September 18. The York Imperial were from Winchester, Va., and were placed in commercial cold storage at that point on October 1. The apple-scald notes on the Grimes were taken December 20 and those on the York Imperial March 12. Both lots were held at a temperature of 20° C. (68° F.) for a period of three days before the notes were taken. See Table XVII.

The results in Tables XV, XVI, and XVII give conclusive proof that there is a wide range of materials that are capable of absorbing the harmful substances produced in apple storage. With some of the materials, such as oatmeal and granulated cork, a part of the good

effects might possibly be attributed to the influence upon humidity; but the results as a whole require a different explanation. As was pointed out earlier in the paper (p. 216) it seems practically certain that the beneficial effects, particularly of the waxes, fats, and oils, are due to their power of absorbing esters or other similar products thrown off in gaseous form by the apple.

TABLE XVII.—*Apple wrappers in commercial barrel storage*

Kind of wrapper.	Percentage of scald.					
	Grimes.			York Imperial.		
	Wrapped.	Not wrapped.	Next layer to wrapped apples.	Wrapped.	Not wrapped.	Next layer to wrapped apples.
None, control barrels		38			40	
Commercial, no wax or oil	27		30	28		30
Paraffin A	18		33	35		30
Paraffin B	15		23	10		30
Paraffin C	23		32	20		
Beeswax 30 per cent, vaselin 70 per cent	9		23	2		35
Beeswax 30 per cent, oilve oil 70 per cent	18		33	5		18
Cacoa butter 70 per cent, olive oil 30 per cent	8		32	1		12
Mineral oil	0		18			

The results furnish some very interesting contrasts. In most tests the commercial wrappers caused little or no reduction in scald, and the paraffin wrappers were but little better, while nearly all the other wrappers caused a decided decrease in the disease. Particularly good results were obtained with fats like cow butter and tallow and with neat's foot oil and mineral oils. It should be noted that there is a close correlation between the ability of the various substances to control apple-scald and their capacity for absorbing gases.

A very significant point is brought out in Table XVII in the extension of the scald reduction to the apples that were adjacent to the wrapped ones. With some of the more efficient wrappers the scald on the contiguous fruit was reduced to less than one-half of that on the fruit in other barrels or in the distant parts of the same barrel. In most cases this effect extended only to apples actually in contact with the wrapped apples, but with the olive and mineral oil wrappers there was an evident decrease in scald at a distance of several layers from the wrapped fruit. These results can hardly be explained by any other theory than that the good effects of the wrappers are largely due to the gas-absorbing capacity of the fats and oils they contain.

PRACTICAL CONSIDERATION

In recording the percentages of scald in the foregoing experiments, consideration has been given to both the number of apples affected and the intensity of the disease; the scald ratings therefore bear a very close relation to the actual damage done to the fruit and to the reduction in price resulting from it. In an average market, the loss in price on the apples would be about half that of the percentage of scald recorded—for example, apples that have been marked as having 80 per cent of scald would ordinarily be sold at a reduction of about 40 per cent in price, apples having 50 per cent of scald at a reduction of 25 per cent, and apples having 5 or 10 per cent of scald at little or no reduction. It is possible, therefore, to obtain a fairly close estimate of the effect of the various treatments upon the value of the fruit. It will be seen by reference to Table XII that barreled apples stored in the bottom of the stack at a distance from the window were damaged by scald to the extent of 40 per cent of their value (80 per cent of scald), while similar apples near the window or in the aisles were damaged but 15 per cent, and the apples in the ventilated barrels but 6 per cent—an amount that might be entirely overlooked in many markets. In the wrapper experiments as shown in Tables XV, XVI, and XVII, the unwrapped apples and those in commercial wrappers were damaged by scald to the extent of from 20 to 40 per cent of their value while those wrapped in the best of the waxed papers were practically free from injury.

These estimates of damage are based on the assumption that the fruit becomes warm before being used. If the apples were sold on a northern market in cold weather, the loss from scald might not be felt by the dealer but be largely passed along to the consumer; but if it were necessary to expose the fruit in moderately warm weather the loss would be shown in the actual selling price. Whether the scald damage becomes evident on the market or only after the fruit has passed to the hands of the consumer, the loss is a real one. Apples that should have remained in good condition for several weeks under common storage conditions are rendered unfit for anything but immediate consumption and even undesirable for that. Not only does the scalded condition gradually spread to considerable depth in the tissue of the apple but the death of the skin exposes the softer tissues beneath to the action of blue mold (*Penicillium expansum*) and other rot organisms, and rapid decay follows. Apples with a sound epidermis are practically immune to rot at high as well as low temperatures (*3*), but apples with the skin killed by scald are doomed to early destruction.

In the apple trade the time at which scald appears on the fruit receives more consideration than the severity of the disease when it occurs. Anything that will postpone the development of apple-scald means a

greater freedom in marketing and fewer rush sales. In the experiments that have been reported no statements have been made as to the time when scald first appeared on the different lots of fruit, but a record was kept of this whenever possible. In the experiment reported in Table XII the York Imperial apples in commercial barrels in the aisle had 32 per cent of scald on January 28, and those in ventilated barrels 10 per cent of scald. On March 12, approximately 6 weeks later, the apples in the ventilated barrels had increased in scald, but only to 18 per cent, and, as is shown in Table XVII, the apples of this same lot that were in the best grade of wrappers were still entirely free from scald. It was impossible to obtain an early record of the apples in commercial barrels in the bottom of the stack (Table XII); but judging from the usual rate of development and the fact that they had 89 per cent of scald on January 28 it is probable that they had 20 to 30 per cent of scald by January 1. In other words, York Imperial apples in commercial barrels in the bottom of the stack were scalded badly enough to have their market value affected by January 1; similar apples in the aisle did not reach the same degree of scald till 4 weeks later; those in ventilated barrels in the aisle had scarcely reached it at the end of 10 weeks; and apples in waxed wrappers were entirely free from scald at the end of this period. What this means to the trade can be readily seen. On the one hand, apples must either be sold so early as to be out of season, or else disposed of for immediate consumption at a later date; on the other hand, if the fruit receives sufficient aeration in storage or is protected by oiled wrappers the dealer may choose his own time for selling and can expose his fruit on the market or ship it to distant points without fear of its going down with scald.

A study of the market products as they pass to the consumer will convince anyone of the enormous food and money losses resulting from apple-scald. It is the opinion of the writers that with the present method of handling apples the losses from this disease are greater than those from all other transportation and storage diseases of the apple, but in spite of all this direct loss it seems to them that the greatest injury to the apple trade comes from the effects of scald upon public confidence. A dealer or consumer buys with the assurance that the apples are of high quality and in good condition, and the seller may really believe them to be; but if the fruit becomes somewhat warmer before the buyer has an opportunity to inspect it he finds a scalded, rotten-looking lot of apples and naturally concludes that he has been cheated. At the present time there is much discussion as to the best methods of increasing apple consumption by increasing exports to foreign countries, extending the trade in the South, and increasing the shipments to small cities that can not handle car load lots. Apple-scald is one of the great barriers to this trade expansion, the disease not only often making it impossible to deliver

fruit in good condition but serving also as a continual source of misunderstanding.

The actaul losses caused by scald and the uncertainty it introduces into the apple trade add greatly to the cost of market operation and help to widen the gap between the producer's and the consumer's prices. The foregoing experiments show that it is a preventable disease and that with proper methods of handling the apples in the orchard and in transportation and storage the disease can be reduced to a negligible quantity if not entirely eliminated.

SUMMARY

(1) The foregoing experiments show that the occurrence of apple-scald is determined by orchard, packing house, transportation, and storage conditions.

(2) As has been shown by other investigators, mature fruit has in general scalded less than immature; but it has also been found that the fruit surfaces just changing from green to yellow have scalded worse than those that were a leaf green and worse than those that had more completely changed to yellow. Well-colored red fruit surfaces have been practically immune to scald.

(3) Apples from trees receiving heavy irrigation have scalded worse than those from trees receiving light irrigation. This was found not to be due to the greater number of large apples in the former case but to some forcing effect that increased the susceptibility to scald in both large and small apples.

(4) Delayed storage has increased or decreased apple-scald, depending upon the amount of aeration the apples received during delay.

(5) Apples in ventilated barrels have developed less than one-third as much scald as those in commercial barrels when both were held in a storage room that received an occasional ventilation, but where the storage room received little or no ventilation the ventilated barrels caused but little decrease in scald.

(6) The amount of scald developed in cold-storage plants has varied greatly with the location in the room. Apples near the aisle or near a door have scalded far less than those in the bottom of the stack. Boxed apples exposed to a continuous air current of 0.88 mile per hour in a commercial storage plant have been practically free from scald, while similar apples that did not receive the constant fanning became badly scalded. Stirring of the storage air has been found more important than its renewal in the prevention of apple-scald.

(7) The ordinary commercial apple wrappers have caused but little decrease in scald, and paraffin wrappers have been but slightly better, but wrappers impregnated with various fats and oils have either entirely prevented the disease or reduced it to a negligible quantity. In barrel

experiments in which only part of the fruit was wrapped, scald has been greatly reduced on the apples adjacent to the wrapped ones as well as on the wrapped apples themselves.

(8) Typical scald has been artificially produced in a few days' time by exposing apples to the vapors of ethyl acelate, amyl acetate, or methyl butyrate.

(9) The manner in which scald can be produced artificially and the different methods of control indicate that the disease is due to the accumulation of esters or similar products of the apple in the tissues of the fruit and in the surrounding air. The vapors of these substances can be carried away by air currents or absorbed by fats and oils.

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